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11 July 1963

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Ballistic Systems Division
Air Force Systems Command
Norton Air Force Base
California

Attention: BSRPQ-1

Subject: "Final Report W2SD-18 Structural Development Test Case M215.02," Report No. MTI-478, dated 12 July 1963, Contract AF 04(647)-243; WS-133A, Minuteman Rocket Motor M-57, Stage III

Reference: Exhibit "D," Paragraph IV.A.3

Gentlemen:

In accordance with Exhibit "D" to Contract AF 04(647)-243, one copy of the subject report is hereby submitted.

Very truly yours,

J. ~~R~~. BONNER, SUPERINTENDENT
AF CONTRACT SUPPORT

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Technical Operating Report
B O B Approval No.________

FINAL REPORT W2SD-18
STRUCTURAL DEVELOPMENT TEST
CASE M215.02

MTI-478

WEAPON SYSTEM 133A

12 July 1963

Contract Number AF 04(647)-243
Exhibit D, Paragraph IV.A.3

Prepared by

HERCULES POWDER COMPANY
CHEMICAL PROPULSION DIVISION
Bacchus Works
Magna, Utah

Prepared for

HEADQUARTERS
AIR FORCE SYSTEMS COMMAND
United States Air Force
Los Angeles, California

Report No. MTI-478

Copy No. 10

Date 12 July 1963

FINAL REPORT W2SD-18
STRUCTURAL DEVELOPMENT TEST
CASE M215.02

Weapon System 133A

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FOREWORD

This report outlines work accomplished by the Case Design Group, Chemical Propulsion Division at the Bacchus Works of Hercules Powder Company for the continued development of Rocket Motor M-57, Minuteman Stage III.

Authority for preparation of this report is specified in Contract AF 04(647)-243, Exhibit D, Paragraph IV.A.3.

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Magna, Utah

ABSTRACT

Structural development test W2SD-18, Case M215.02, was conducted at the Bacchus Works, Hercules Powder Company on 10 March 1962 to determine the structural integrity of the Wing II, M-57E1 rocket motor case when subjected to flight load conditions of axial load, shear load, and bending moment conducted at room temperature environment.

Case M215.02 failed under the combined effects of an axial load of 65.5 kips, a shear load of 6.5 kips, and a bending moment of 1194.3 in.-kips.

From the test results, an average Poisson's ratio of 0.1936 and a compressive modulus of elasticity of 4.88 x 10^6 psi were calculated for the cylindrical section of the case.

It was concluded that the Wing II case represented in this test is capable of withstanding the structural requirements imposed on the aft tangent line during the maximum $q\alpha$ (See Boeing document D2-3877-4) condition experienced during first stage action time.

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INTRODUCTION

A. PURPOSE

Structural development test W2SD-18 was conducted as a part of a Wing II Continued Development Program in the development of a lighter weight case for the third stage Minuteman. This test, a duplicate of test W2SD-17, was carried out to determine whether the light weight case design would meet the required flight load conditions as specified in Boeing Document D2-3877-4.

The purpose of this test was to gain information in determining the structural integrity of the new Wing II M-57E1 rocket motor case under simulated flight requirements of combined axial load, shear load, and bending moment at room temperature.

The test was conducted 10 March 1962 by Hercules Powder Company at facilities located at Bacchus, Utah.

B. TEST OBJECTIVES

Test objectives were:

(1) To determine the physical capabilities of the aft tangent line area of the Wing II M-57E1 rocket motor case under combined external loading of axial load, shear load, and bending moment at room temperature.

(2) To determine modulus of elasticity and Poisson's ratio values for the critical areas of the case at room temperature.

SECTION II

TECHNICAL DISCUSSION

A. TEST SPECIMEN DESCRIPTION

The test specimen was a standard Wing II rocket motor case (Ref: HPC drawing 01A00221) number M215.02 which was constructed of Spiralloy. The nominal outside diameter was 37.5 in. The distance between tangent lines was 43.0 in. The case configuration is described in the following paragraphs.

1. Cylindrical Section

The cylindrical section of the case consisted of seven layers of 90° windings and six layers of 14.5° helical windings; the thrust termination (TT) port areas were each additionally reinforced with six glass wafers and six TT ply mats. The theoretical thickness was 0.16 in. except in the TT port reinforced area. (The case was pressurized to 50 psig to simulate structural support received from propellant.)

2. Domes

The forward and aft domes were each wound with four layers of 14.5° windings; the nozzle port areas on the aft dome were additionally reinforced with four glass wafers which were 16 in., 17 in., 18 in., and 19 in. in diameter, respectively. The minimum theoretical thickness at the tangent line was 0.06 in.

3. Forward Skirt

The forward skirt build-up consisted of two layers of 14.5° windings, nine layers of reverse 143 weave glass cloth, one layer of 90° windings, and three layers of 90° nylon roving. The nominal wall thickness was 0.17 in. and the length was 12.575 in. measured from the forward tangent line. For additional reinforcement of the forward skirt for this test, ten layers of 181 weave glass cloth were also applied to the external surface of the forward skirt. A 0.250 in. thick aluminum ring sleeve was internally bonded to the inner surface of the skirt, and the forward Y-joints were filled with Armstrong C-7 epoxy. (See Figure 1.)

4. Aft Skirt

The aft skirt build-up consisted of two layers of 14.5° windings, twenty-two layers of reverse 143 weave glass cloth, one layer of 90° winding, and three layers of 90° nylon roving. The nominal wall thickness was 0.313 in. and the length was 6.2 in. measured from the aft tangent line.

A two-cycle cure of the resin was used in the manufacture of this case. The lamination materials used were Union Carbide's ERLA 2256 resin and HTS 144 ends/in. glass roving.

In preparation for the test, a metal-reinforced R & D section was attached to the forward skirt and a reinforced second-to-third stage interstage section was fastened to the aft skirt.

B. TEST PROCEDURE

After installation of the instrumentation (Figure 2), the assembly was mounted in an upright position in the compression load testing device as shown in Figure 3. This device consisted of three hydraulic rams designated P_1, P_2, and P_3. Ram P_1 was positioned on the base at point 0^o and ram P_2 at 180^o. P_3 was mounted on the crosshead 70 in. forward from the center of the TT port area at 180^o. The force from P_3 was normal to the longitudinal centerline of the case. A representation of the case installed in the test fixture is shown in Figure 4.

The instrumentation was attached to the recorders and checked out for accuracy (polarity, calibration). After this was completed, the simulated flight loads were applied as programmed on the Y-T plot. (See Figure 5.) The actual traces are shown in Figures 6 through 8.

C. TEST RESULTS

Test objectives were met as indicated by the test results outlined below. Test data are shown graphically in Figures 9 through 11 and are listed in Table I.

The case failed when the plane of weakness between the body and skirt juncture sheared, causing all the structural load to be carried by the skirt windings. (See Figures 12 and 13.) Because of this phenomenon, the skirt windings folded over themselves at the aft tangent line. The above mentioned plane of weakness is caused when the case is cured in two stages; once, after body wind, and again after the skirts have been wound to the unit.

The case was subjected to the following loads when failure occurred:

Axial Compressive Load = 65.5 kips at room temp

Bending Moment = 1194.3 in.-kips at room temp

Shear Load = 6.5 kips at room temp

The above loads were calculated using Figures 6 through 8 for the aft tangent line where failure occurred.

From the equation

$$P_{eq} = P + 2\ M/R$$

where: P_{eq} = equivalent axial compressive load

P = applied axial compressive load

M = applied bending moment

R = distance in in. from the case longitudinal centerline to the point of calculation ($R = 18.75$)

The above equivalent axial compressive load is 192.9 kips.

The loads that the case was required to withstand as dictated by STL at the time the test was conducted, were:

Axial compressive load = 56 kips at 150° F

Bending moment = 1200 in.-kips at 150° F

Shear load = 6.5 kips at 105° F

The above load condition gives an equivalent axial compressive load of 184 kips.

The final design requirements for the aft tangent line per Boeing document Number D2-3877-4 (max $q\alpha$ condition) are:

Axial compressive load = 47.4 kips at 150° F

Bending moment = 727.9 in.-kips at 150° F

Shear load = 4.24 kips at 150° F

The above load combination corresponds to an equivalent axial compressive load of 125.1 kips.

The above required load of 125.1 kips simulates the load experienced by the third stage case aft tangent line during first stage operating condition (max $q\alpha$). The theoretical surface temperature of the case during this period of flight is 150° F. At the above temperature the critical buckling stress of the case degradates 7 percent. The ratio of 125.1 kips over 0.93 gives a value of 134.5 kips. This value is the room temperature requirement corresponding to the value required at 150° F.

The ratio of 192.9 kips to 134.5 kips gives a margin of safety of 1.43. This is in excess of design requirements which include a 1.25 safety factor.

During the instrumentation checkout pre-test load cycle, the case was accidentally subjected to a bending moment of 1,200 in.-kips at the aft tangent line. The affect of this bending moment on the ultimate capability of the case is unknown.

The average Poisson's ratio for the cylindrical section between the TT ports is 0.1936. This value was obtained from gages J, K, P, and N and agrees favorably with past data.

Using strain gage N, the compressive modulus of elasticity (E), is 4.88×10^6 psi; this value is high but not impractical. Electronic deflection indicators (EDI) 3 and 6 show an average E of 6.45×10^6 psi for the cylindrical section forward of the TT ports. The value for this area, from past tests on cases of this design, is 3.5×10^6 psi; the reason for the high modulus (E) on this test case is unknown.

Structural test W2SD-17 was identical to this test on a case of the same design. Refer to Hercules Powder Company document Number MTI-477 for a comparative report.

SECTION III

CONCLUSIONS

From the test results it can definitely be concluded that the Wing II rocket motor case is capable of meeting and exceeding the present structural requirements of the aft tangent line during the first stage operation condition (max $q\alpha$) as defined in Boeing document D2-3877-4.

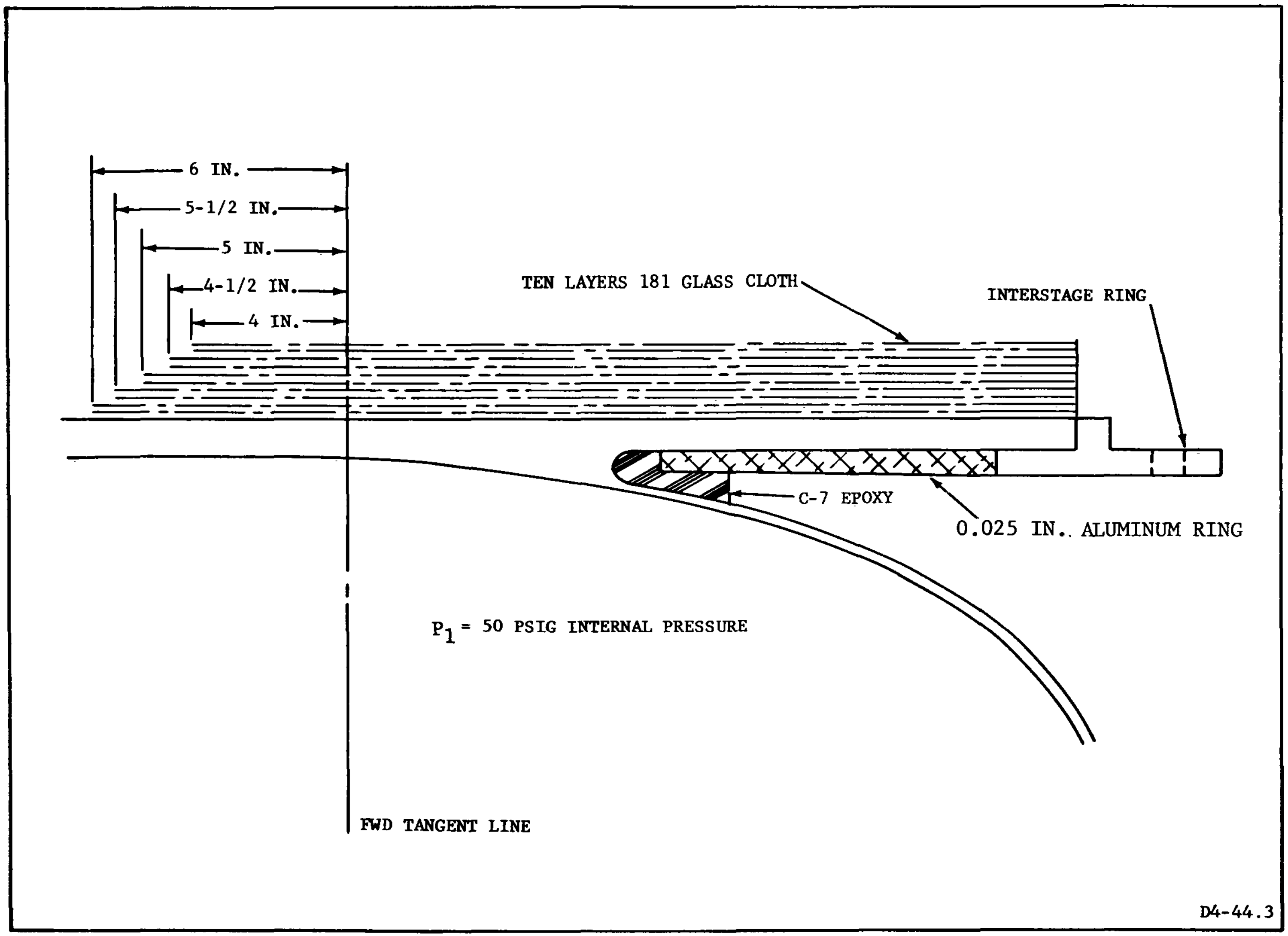

Figure 1. Specimen Reinforcement Diagram

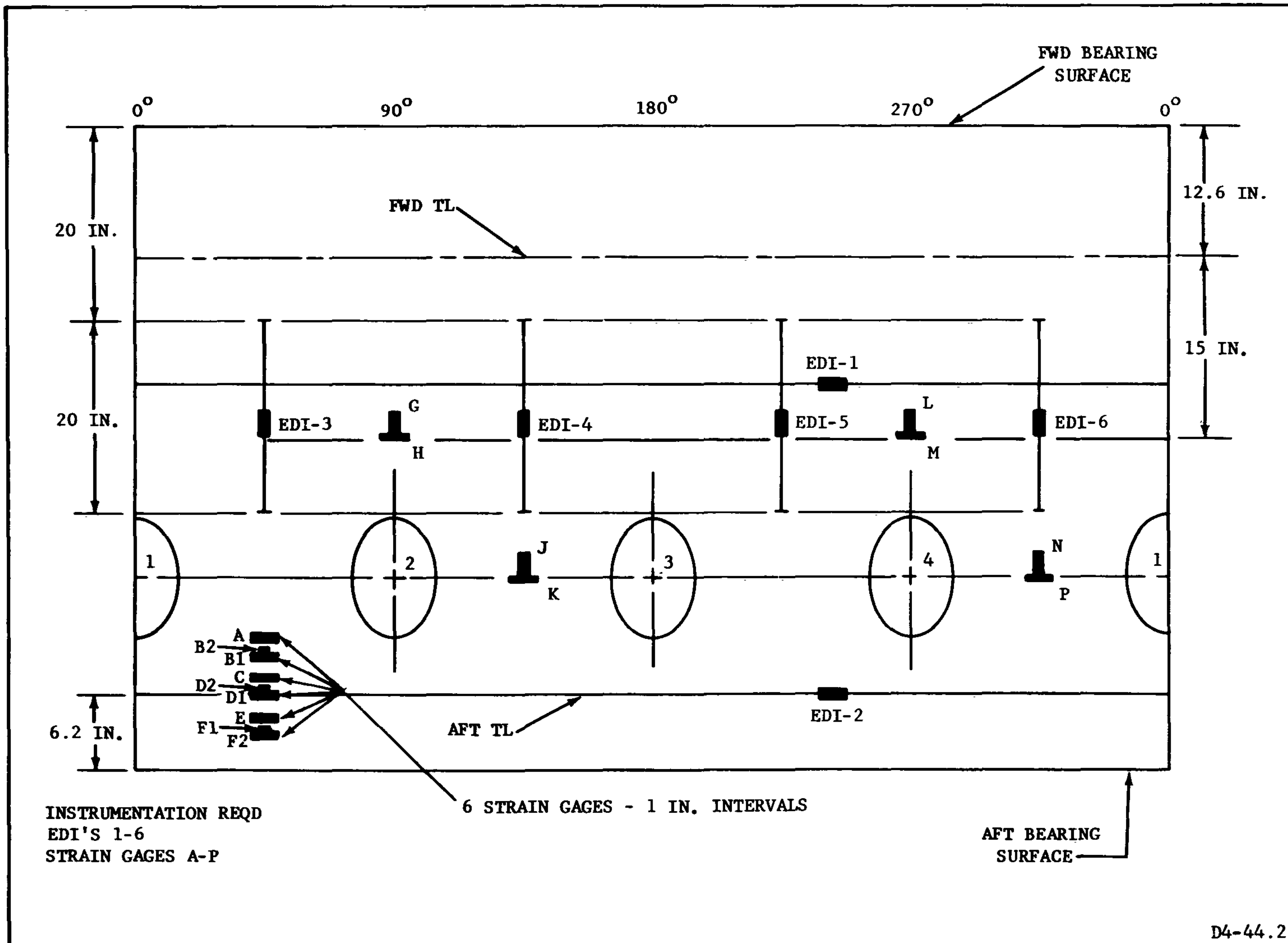

Figure 2. Instrumentation Location

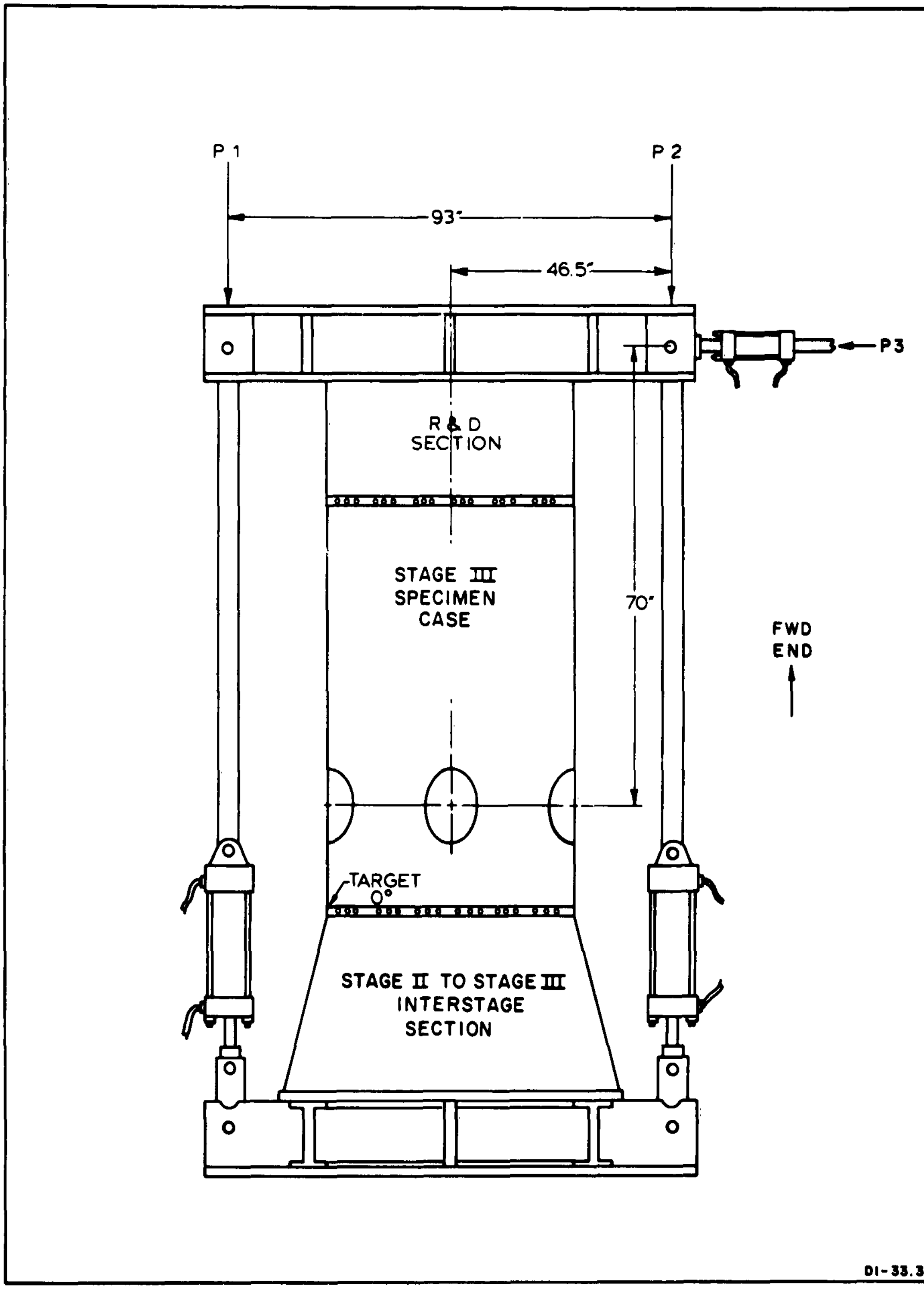

Figure 3. Test Setup

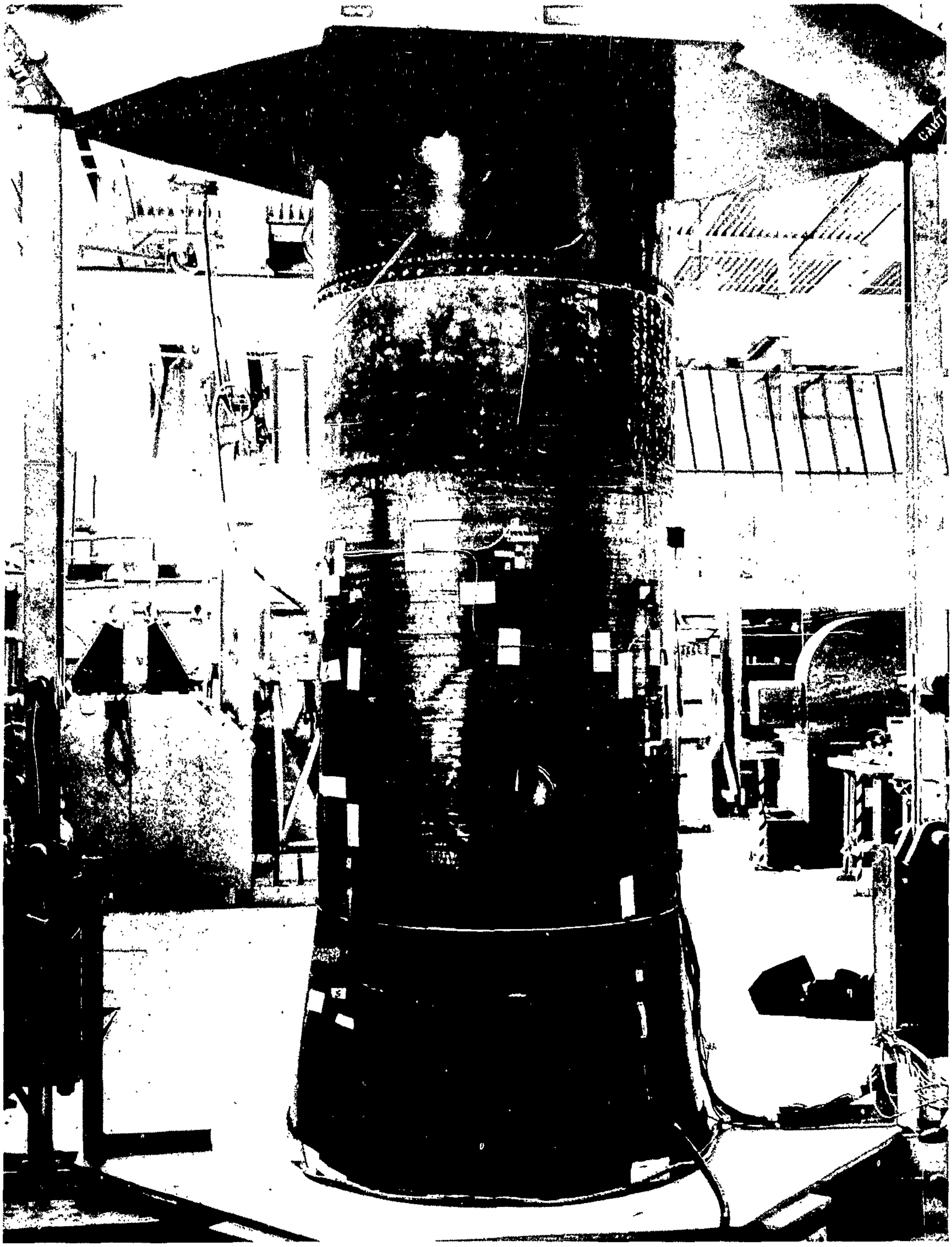

Figure 4. Case in Test Fixture (Representation)

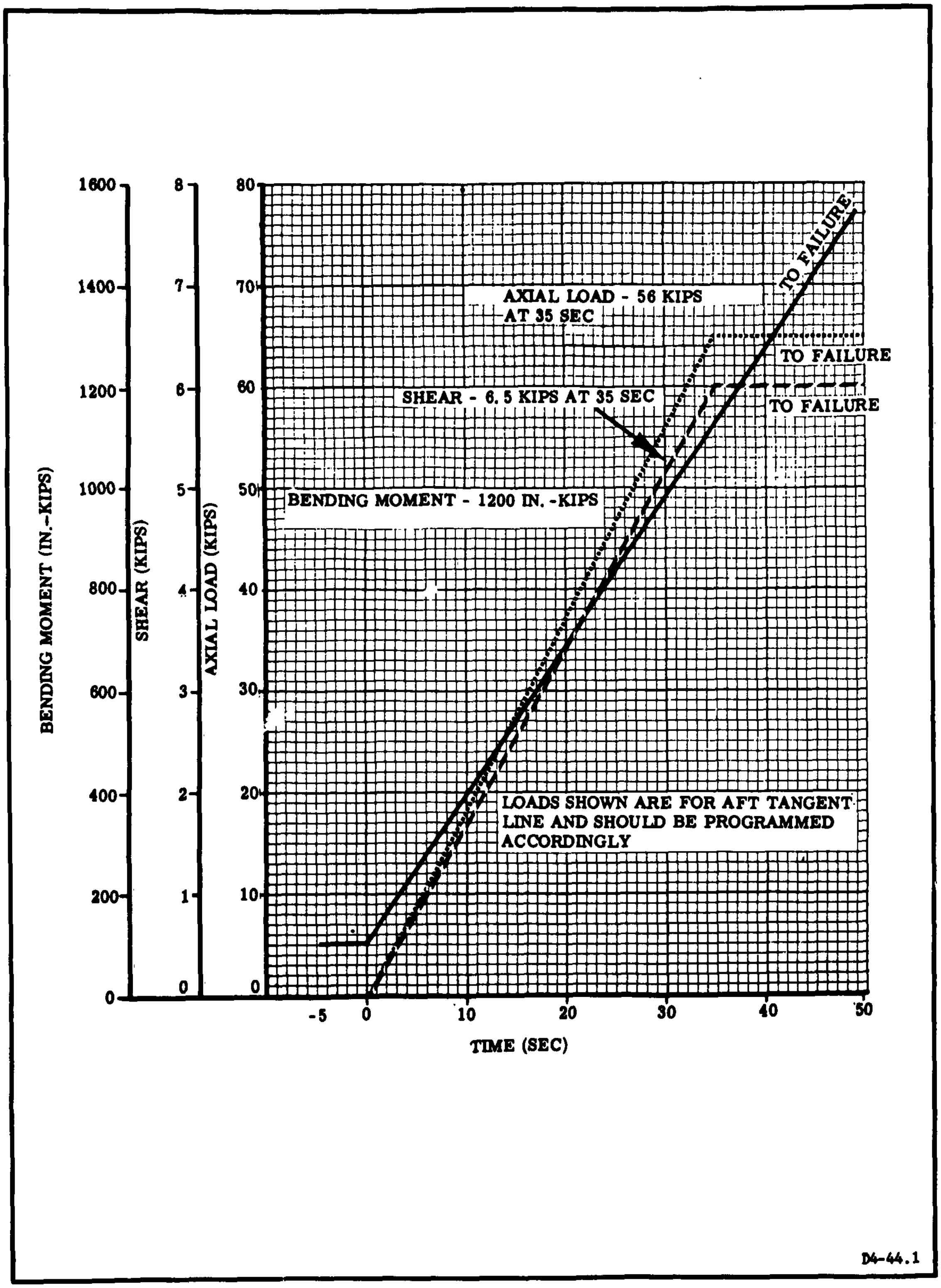

Figure 5. Programmed Load (Y - T Plot)

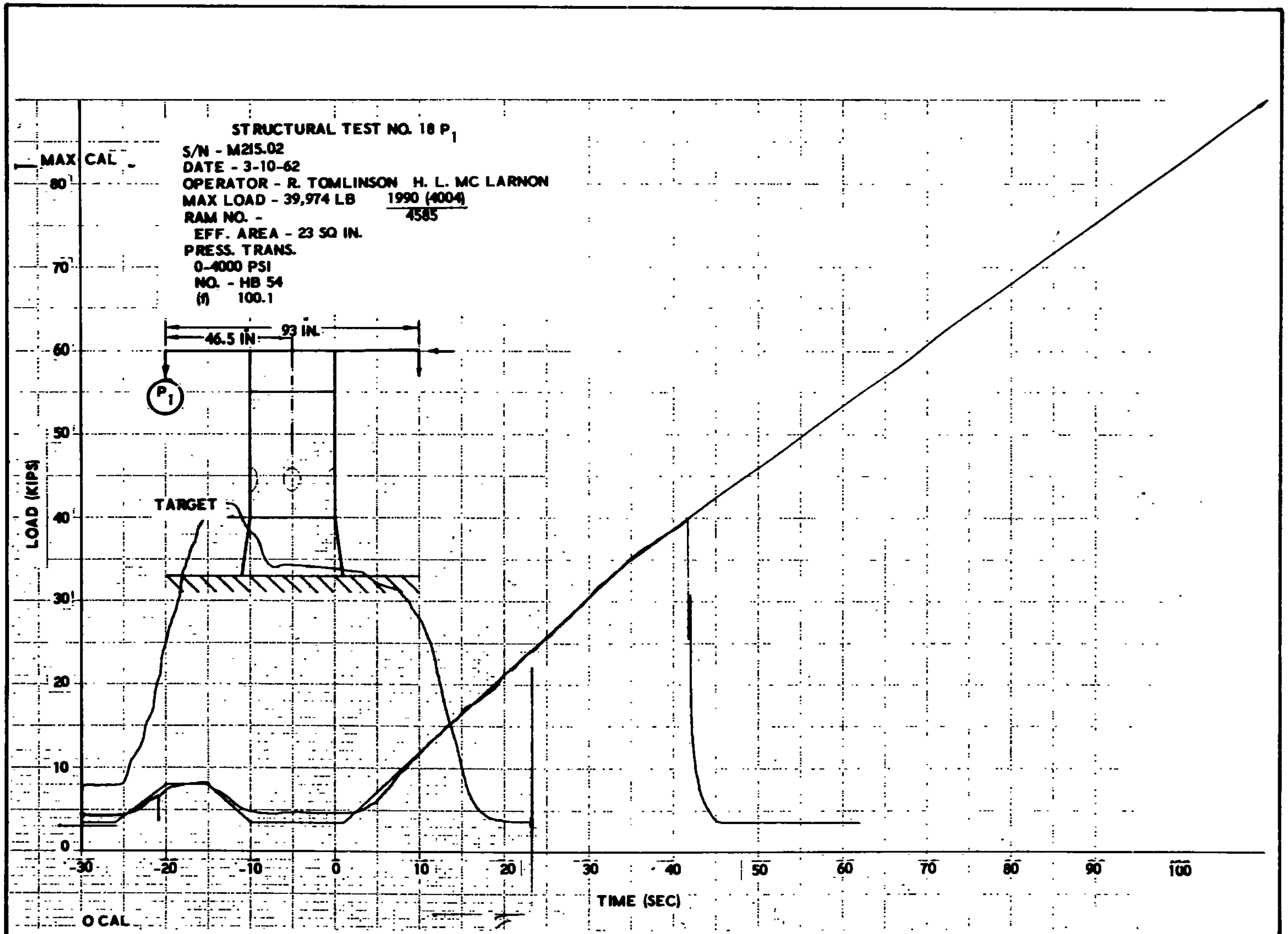

Figure 6. P_1 Compressive Load vs Time Trace

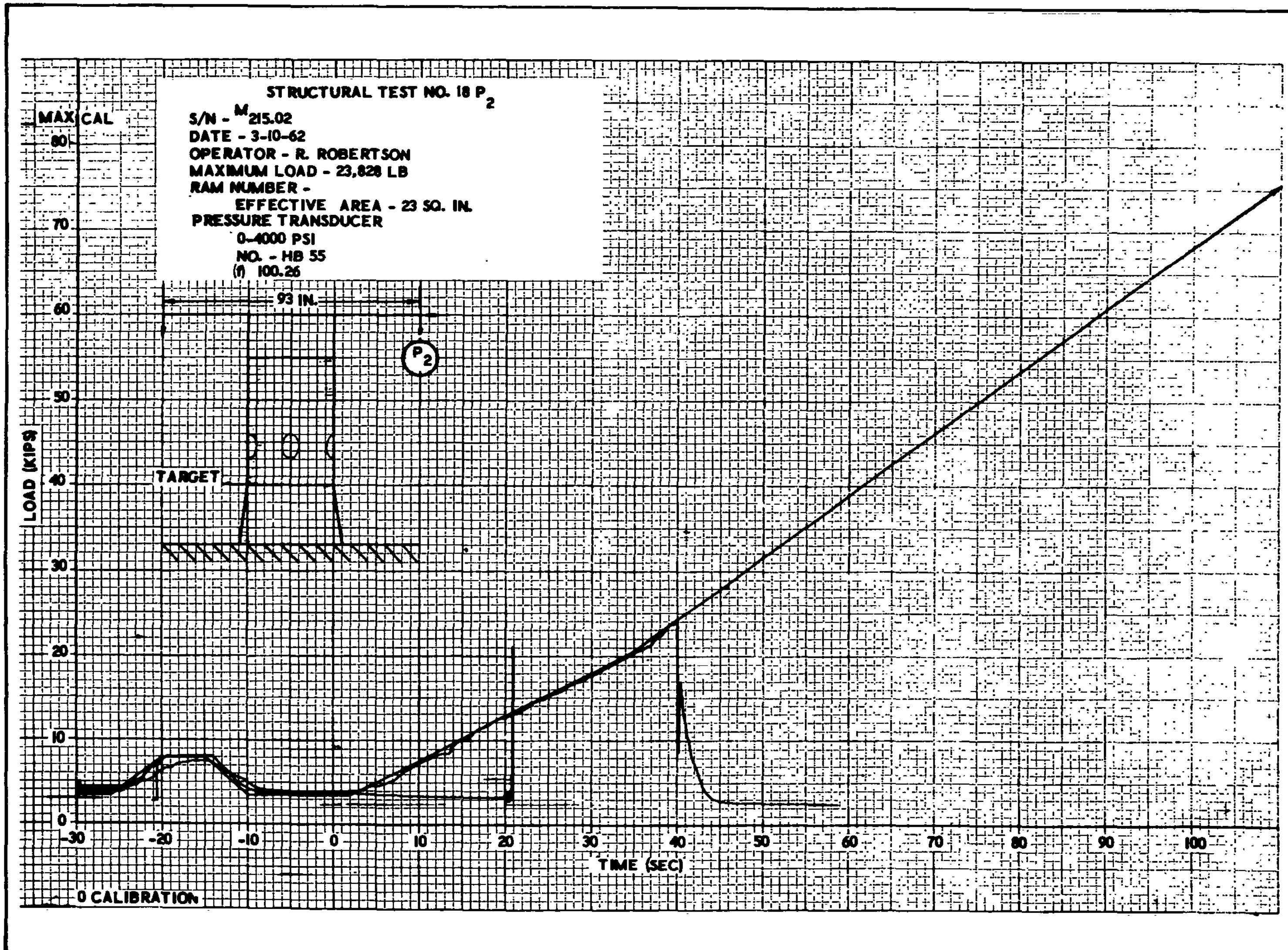

Figure 7. P_2 Compressive Load vs Time Trace

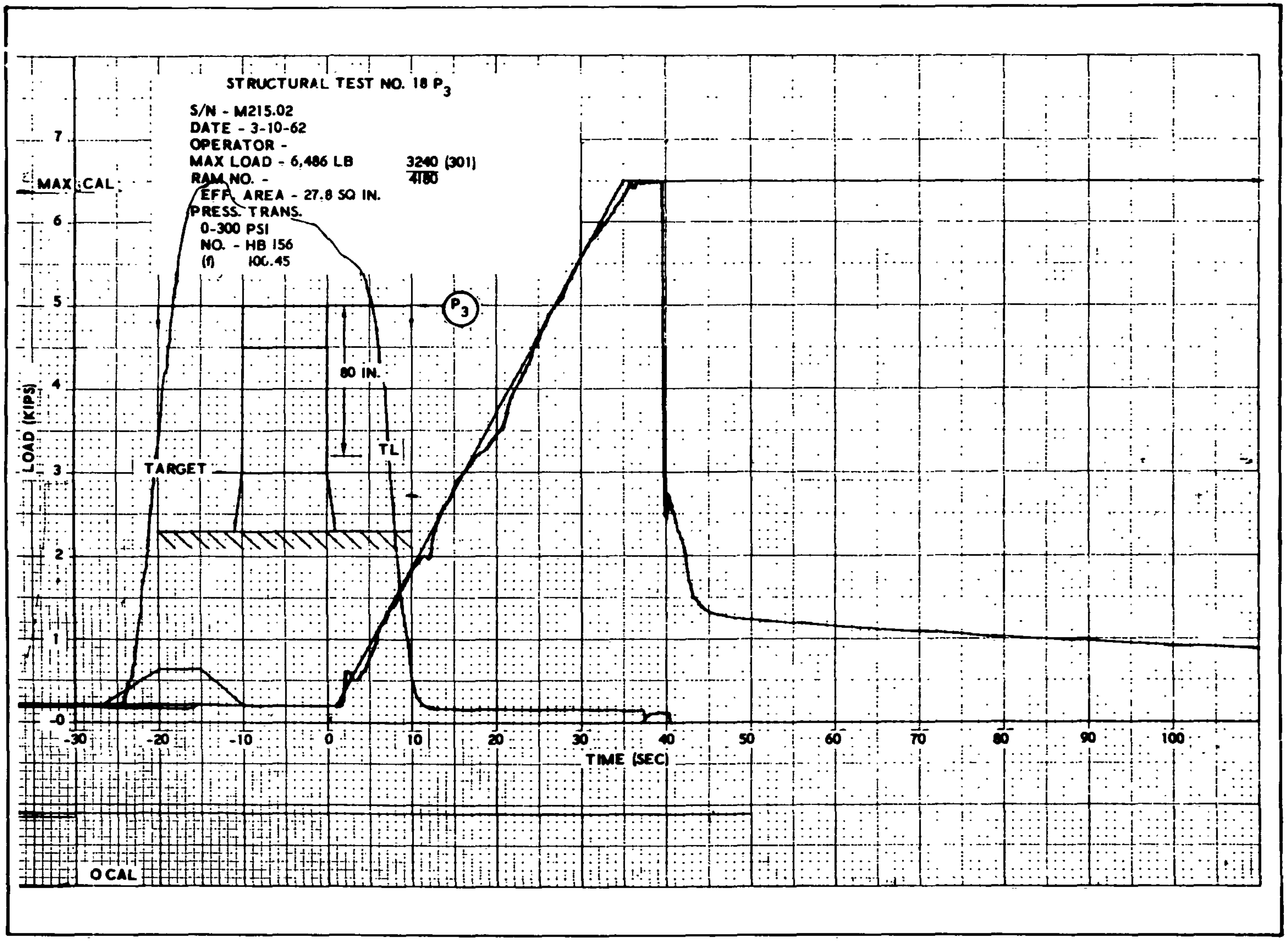

Figure 8. P_3 Shear Load vs Time Trace

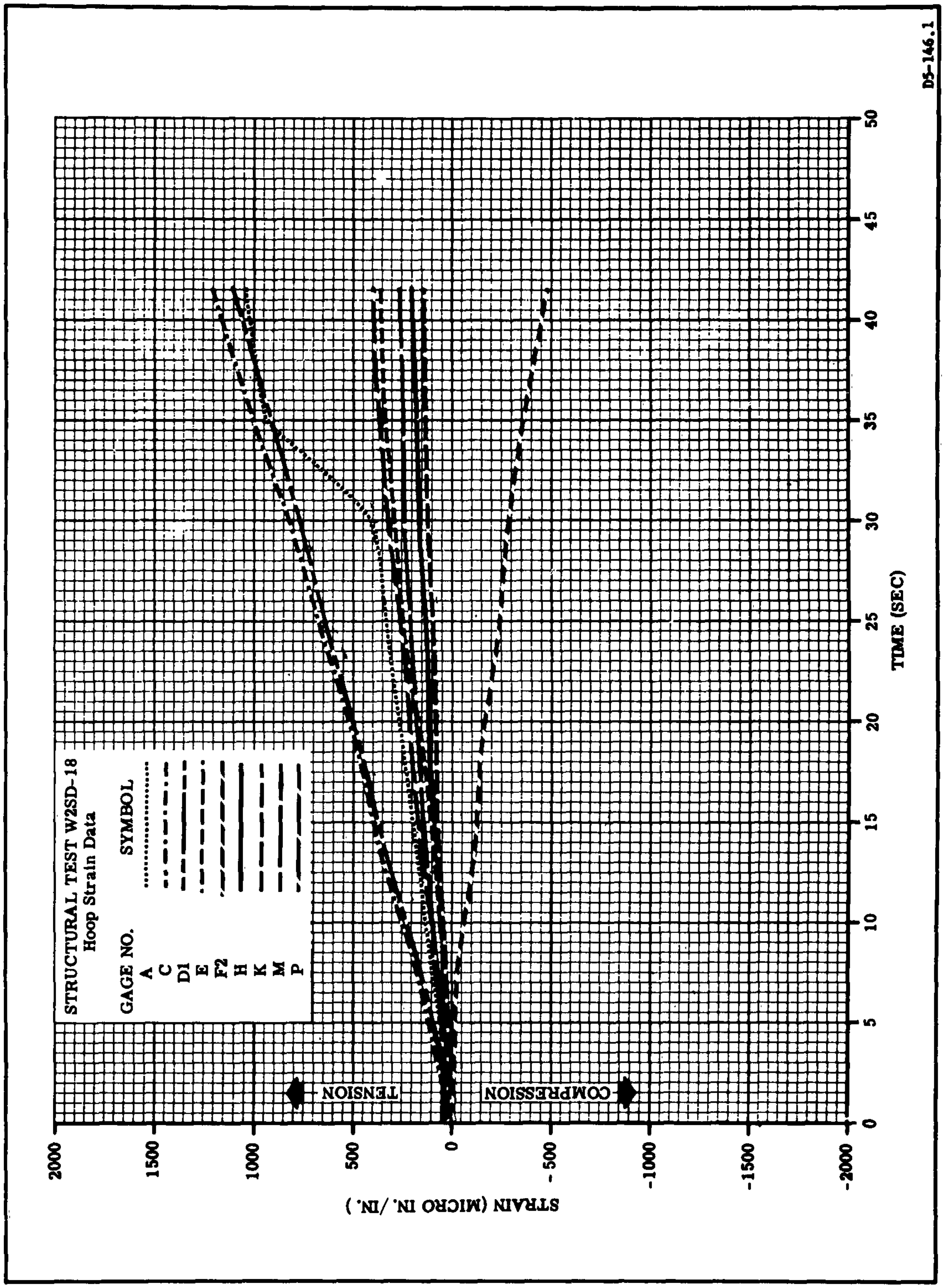

Figure 9. Hoop Strain vs Time

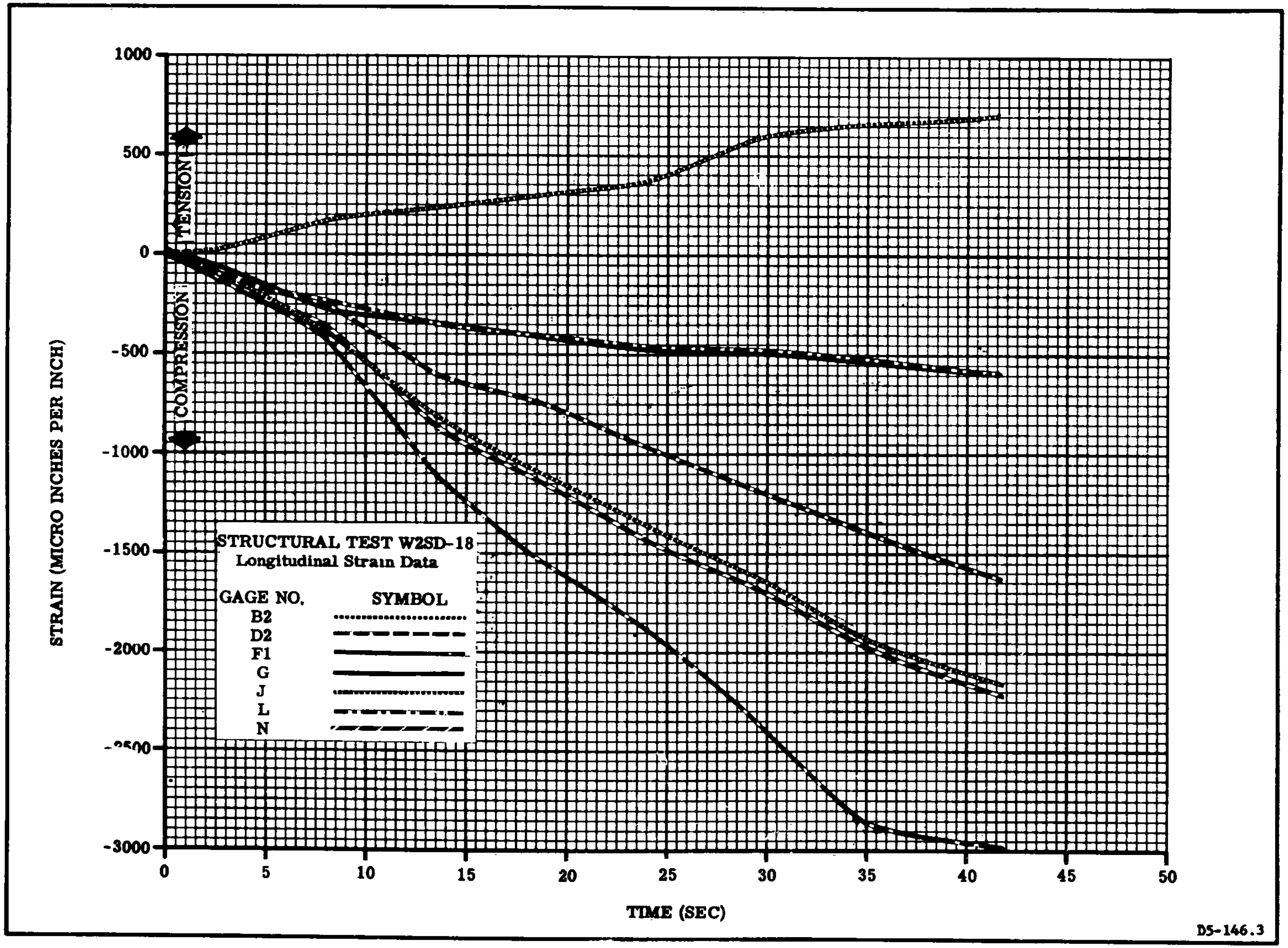

Figure 10. Longitudinal Strain vs Time

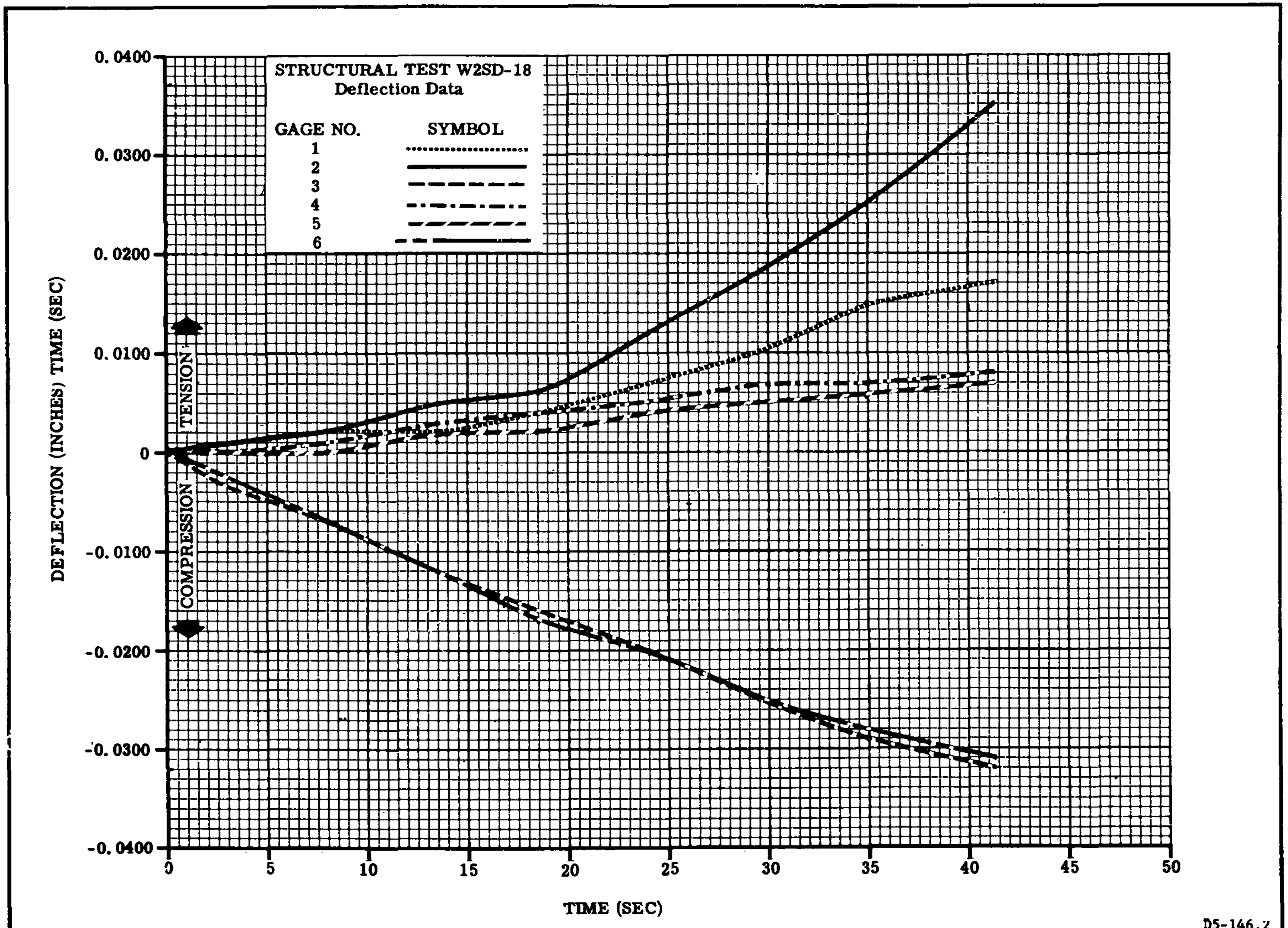

Figure 11. Deflection vs Time

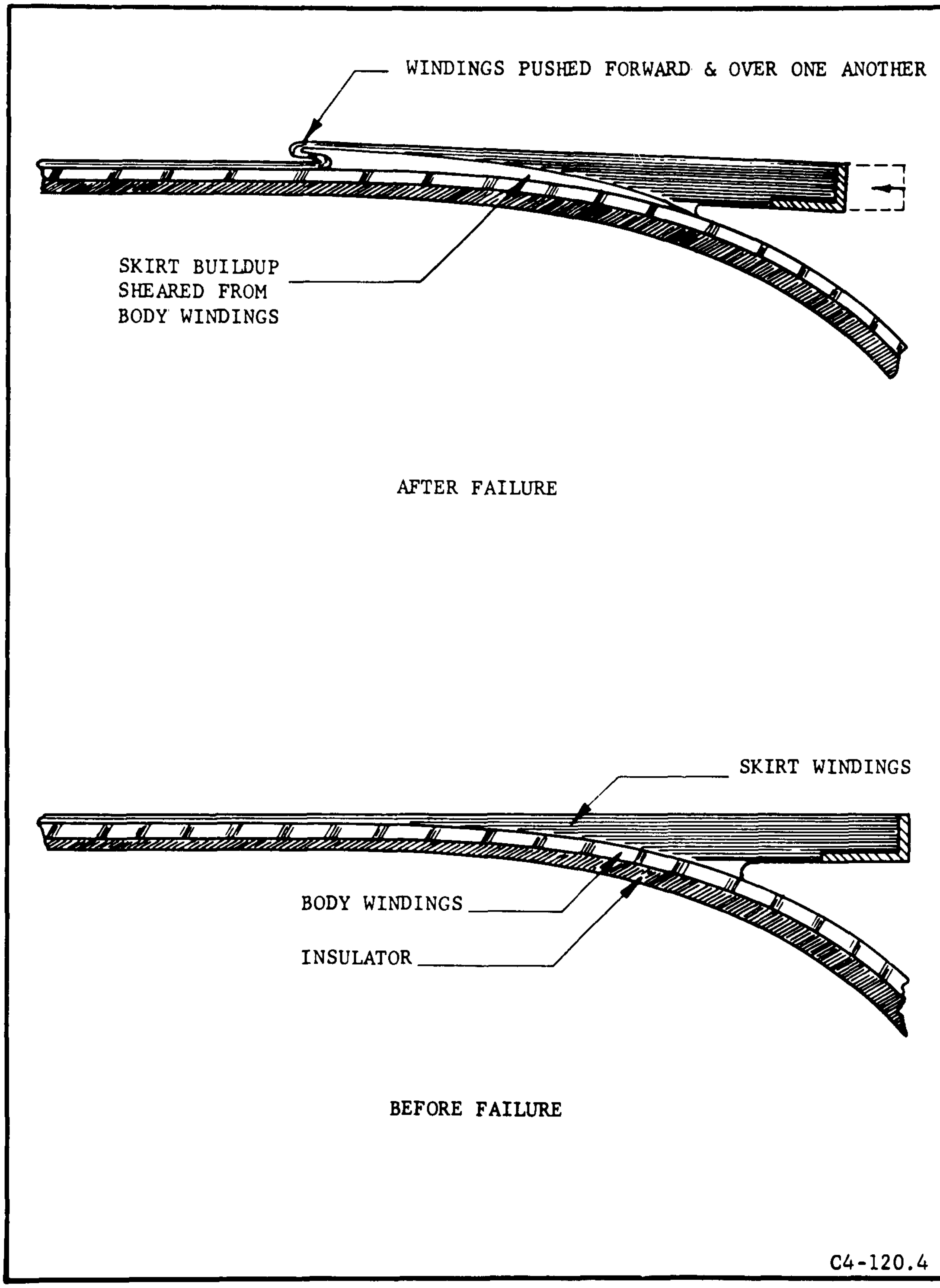

Figure 12. Failure Area Schematic

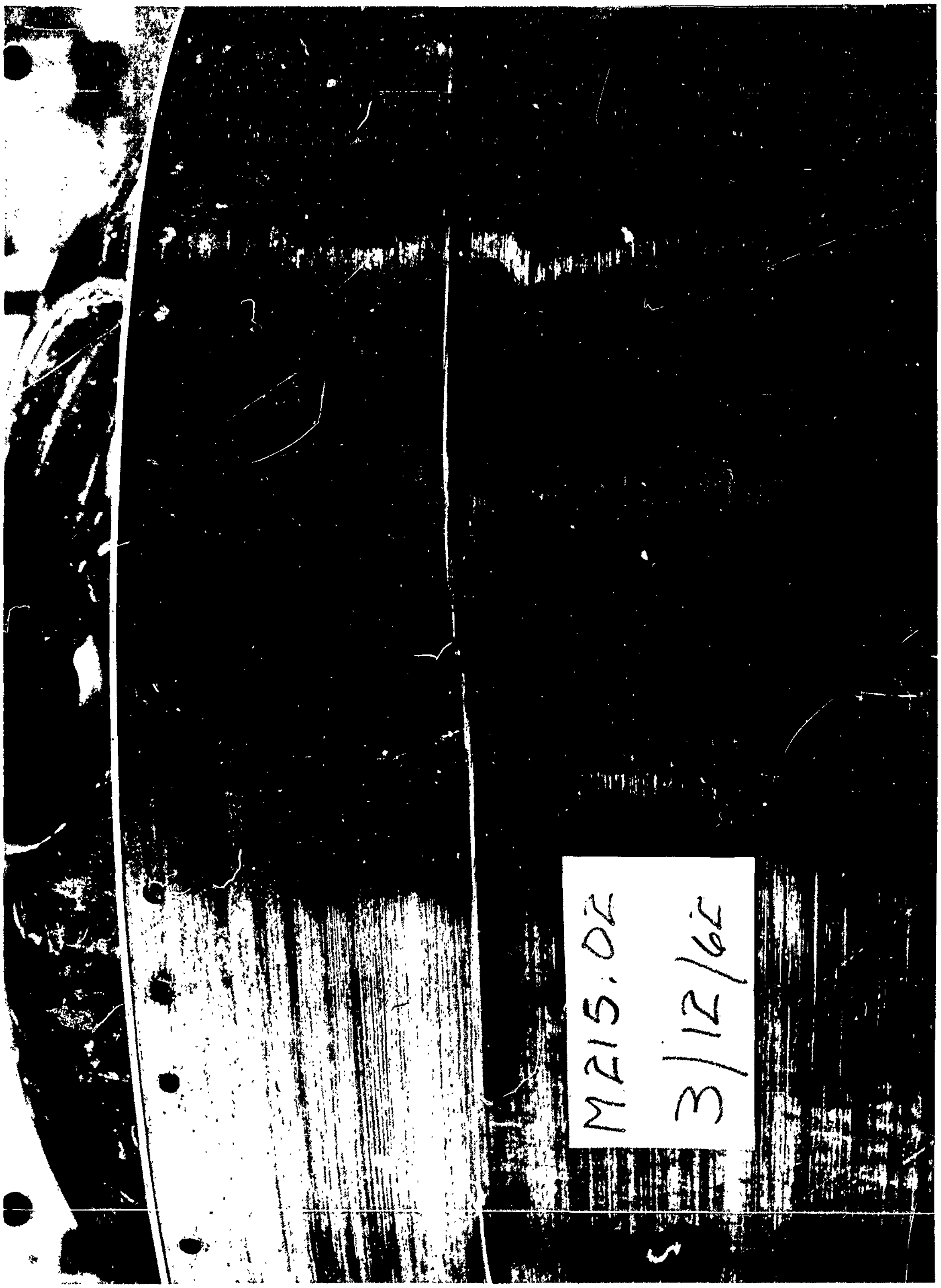

Figure 13. Failure Area

TABLE I

W2SD-18 TEST DATA VS TIME AND LOAD

	TEST TIME IN SECONDS								
	.00	2.60	8.00	13.40	18.60	24.00	29.50	34.90	41.62
				APPLIED RAM LOADS IN KIPS					
P1	3.500	5.000	10.000	15.000	20.000	25.000	30.000	35.000	40.000
P2	3.500	3.900	6.000	8.500	12.000	14.700	17.700	20.100	25.500
P3	.100	.500	1.500	2.500	3.300	4.400	5.500	6.290	6.500
				STRAIN IN MICRO INCHES PER INCH					
SGA	4.009	20.045	104.236	184.418	244.554	320.727	380.863	449.018	549.245
SGB1	.000	.000	.000	.000	.000	.000	.000	.000	.000
SGB2	-13.504	-94.528	-391.616	-810.240	-1066.816	-1363.904	-1620.480	-1944.576	-2166.640
SGC	40.090	60.136	180.409	360.818	485.100	649.472	801.818	1002.272	1206.736
SGD1	39.911	43.902	159.647	335.258	458.985	618.632	758.323	917.970	1105.555
SGD2	-60.285	-120.571	-253.199	-602.857	-735.485	-964.571	-1181.599	-1398.628	-1627.714
SGE	18.900	23.625	47.250	94.500	146.475	231.525	278.775	330.750	354.375
SGF1	3.991	-79.823	-419.073	-1117.529	-1536.602	-1875.852	-2354.794	-2953.470	-3552.147
SGG	-11.981	-59.909	-179.727	-347.472	-419.363	-479.272	-491.254	-539.181	-599.090
SGH	4.009	12.027	44.100	80.181	116.263	124.281	160.363	180.409	205.454
SGJ	59.909	11.981	179.727	239.636	299.545	359.454	599.090	658.999	718.909
SGK	20.045	28.063	40.090	64.145	80.181	96.218	120.272	128.290	146.336
SGL	-107.836	-131.800	-239.636	-359.454	-419.363	-467.290	-479.272	-527.199	-599.390
SGM	40.090	52.118	80.181	132.300	160.363	200.454	236.536	248.563	280.636
SGN	-59.909	-131.800	-359.454	-874.672	-1138.272	-1437.818	-1677.454	-1977.000	-2216.636
SGP	20.045	40.090	80.181	160.363	200.454	240.545	320.727	360.818	400.909
SGF2	12.057	-12.057	-24.114	-120.571	-144.685	-229.085	-277.314	-361.714	-482.285
				DEFLECTION IN INCHES					
ED11	.001	.001	.002	.002	.004	.007	.010	.015	.017
ED12	.000	.001	.002	.005	.006	.012	.018	.025	.035
ED13	-.001	-.002	-.007	-.012	-.016	-.020	-.025	-.029	-.032
ED14	-.000	-.000	.001	.003	.004	.005	.007	.007	.008
ED15	-.001	-.000	.000	.002	.002	.004	.005	.006	.007
ED16	-.000	-.002	-.007	-.012	-.017	-.020	-.025	-.028	-.031
END									

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